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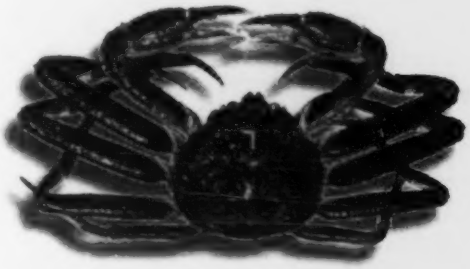
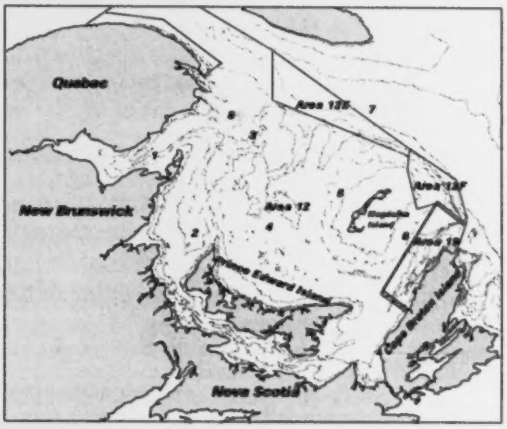
Gulf Region
Canadian Science Advisory Secretariat
Science Advisory Report 2012/003

ASSESSMENT OF SNOW CRAB IN THE SOUTHERN GULF OF ST. LAWRENCE (AREAS 12, 19, 12E AND 12F) AND ADVICE FOR THE 2012 FISHERY





1. Chaleur Bay
2. Shediac Valley
3. Orphan Bank
4. Bradelle Bank
5. Magdalen Channel
6. Cape Breton Corridor
7. Laurentian Channel
8. American Bank

Figure 1: Map of the southern Gulf of St. Lawrence showing the Crab Fishing Areas (CFAs), fishing grounds and management buffer zones (shaded area).

Context

Snow crab, Chionoecetes opilio, has been commercially exploited in the southern Gulf of St. Lawrence since the mid 1960s. There are four individually managed fishing areas among which Area 12 (Figure 1) is the largest fishery in terms of its fishable surface, number of participants and landings. In Areas 12, 12E and 12F, the fishing season generally starts in April-May as soon as the Gulf is clear of ice and continues into early summer while in Area 19, the fishery opens after June 30 and usually ends in mid-September. The landing of females is prohibited and only hard-shelled males ≥ 95 mm of carapace width are commercially exploited.

DFO Gulf Region Fisheries and Aquaculture Management requested an assessment of the resource status in 2011 and catch advice for the 2012 fishery. This document provides an overview of the assessment results and the science advice. Catch rates and other fishery performance indicators are reported. The assessment of the status of the southern Gulf snow crab resource (Areas 12, 19, 12E and 12F) is based on fishery independent trawl surveys that provide indicators of: abundance (commercial biomass), reproductive potential (numerical abundance of mature females), recruitment, and to estimate exploitation rates in the fishery. A science peer review meeting was conducted Feb. 7-8, 2012 in Moncton, NB. Participants at the science review included DFO Science, DFO Fisheries Management, university researchers, an expert from USA, the fishing industry, provincial governments and Aboriginal organizations.

Canada

SUMMARY

- Snow crab in fishing areas 12, 19, 12E, and 12F comprise a single biological population and the southern Gulf of St. Lawrence stock is considered as one unit for assessment purposes.
- The landings of snow crab from the southern Gulf of St. Lawrence in 2011 were 10,708 t from a quota of 10,677 t.
- The assessment in 2011 was conducted as per the recommendations of the Snow Crab Assessment Methods Framework Science Review held during November 21 to 25, 2011, in Moncton, N.B. The major changes to the assessment methodology were the expansion of the biomass estimation polygon (20 to 200 fathoms) to better cover the southern Gulf of St. Lawrence biological unit and the use of catches in weights directly to estimate biomass.
- The changes in methodology required a recalculation of the time series of biomass estimates for 1997 to 2010, exploitation rates, and the Precautionary Approach reference points.
- The exploitation rate of the 2011 fishery in the southern Gulf of St. Lawrence was 29.9%.
- The 2011 post-fishery survey biomass of commercial-sized adult male crabs was estimated at 63,162 t (95% C. I. 55,965 to 71,022 t), an increase of 76% from 2010. The available biomass for the 2012 fishery, derived from the 2011 survey, is within the healthy zone of the Precautionary Approach framework.
- The residual biomass (33,768 t) from the 2011 survey increased by 119% compared to 2010.
- Forty seven percent (47%) of the 2011 survey biomass, available for the 2012 fishery, is composed of new recruitment (29,394 t). The recruitment to the fishery in 2011 increased (44%) relative to the 2010 survey.
- An increasing trend in recruitment of commercial-sized adult male crab to the fishery is anticipated into the 2014 fishery.
- A risk analysis of catch options relative to reference points for the 2012 fishery is provided.

Fishery performance in 2011 by snow crab fishing area

Area 12:

- The 2011 landings in Area 12 were 8,618 t (quota of 8,585 t).
- The CPUE (expressed as kg per trap haul (kg/th)) in 2011 (53.0 kg/th) increased compared to 2010 (47.9 kg/th).
- The incidence of soft-shelled crab remained low at 6.2%, but 233 of 323 grids were closed towards the end of the fishing season in 2011.

Area 19:

- The 2011 landings in Area 19 were 1,701 t (quota of 1,703 t).
- The CPUE in 2011 (133.3 kg/th) increased compared to 2010 (122.1 kg/th) and represents the highest value observed since records began in 1987.
- The incidence of white-crab increased from 6.4% in 2010 to 11.5% in 2011 and no sectors within Area 19 were closed during the fishing season.

Area 12E:

- In Area 12E, the landings were 76 t (quota of 75 t).
- The CPUE in 2011 (31.5 kg/th) increased compared to 2010 (27.4 kg/th).
- The incidence of soft-shelled crab in 2011 decreased to 8.4%, compared to 14.7% in 2010. No grids were closed during the fishing season.

Area 12F:

- The 2011 landings in Area 12F were 313 t (quota of 314 t).
- The CPUE in 2011 (32.5 kg/th) increased compared to 2010 (29.3 kg/th).
- The incidence of soft-shelled crab decreased from 8.6% in 2010 to 2.6% in 2011. No sectors within Area 12F were closed during the fishing season.

BACKGROUND

Species Biology

Snow crab (Chionoecetes opilio) is a crustacean like lobster and shrimp, with a flat, almost circular, body and five pairs of spider-like legs. The hard outer shell is periodically shed in a process called molting. After molting, crabs have a soft shell for a period of 8 to 10 months. Soft-shelled crab is defined by shell hardness (<68 durometer units) and includes both new-soft (condition 1) and clean hard-shelled crab (condition 2). The term white-crab is used in the summer fishery of Area 19 because the newly-molted crabs have reached a relatively harder carapace than those observed during the spring fishery (Areas 12, 12E and 12F). White crab is defined by shell hardness <78 durometer units and includes both new soft (condition 1) and clean hard-shelled crab (condition 2).

Unlike lobsters, snow crabs do not continue to molt throughout their lives. Females stop growing when they acquire a wide abdomen for carrying eggs, which occurs at carapace widths (CW) less than 95mm. Males stop growing when they acquire large claws on the first pair of legs, which can occur at CWs between 40 and 150 mm. Females produce eggs that are carried beneath the abdomen for approximately 2 years. The eggs hatch in late spring or early summer and the newly-hatched crab larvae spend 12-15 weeks in the water column. At the end of this period, they settle on the bottom. It takes at least 8-9 years (post-settlement) for males to reach legal size.

Fishery

Until 1994, the snow crab fishery in Area 12 (Figure 1) was exploited by 130 mid-shore crab harvesters from New Brunswick, Québec and Nova Scotia. Since 1997, the PEI coastal fishery, (formerly Areas 25/26) has been integrated into Area 12. In 2003, a portion of the coastal fishery off Cape Breton (formerly Area 18) was also integrated into Area 12. For the purpose of this assessment, Area 12 refers to the new management unit (Figure 1). The number of licenses in Area 12 was 261 in 2011.

In 1978, Area 19 (Figure 1) was established for the exclusive use of Cape Breton inshore fish harvesters with vessels less than 13.7 m (45 feet) in length. There were 160 licenses in Area 19 in 2011.

Areas 12E and 12F were introduced in 1995 as exploratory fisheries. In 2002, the status of Areas 12E and 12F was changed from exploratory to commercial fishing areas. There are 8 and

18 crab harvesters in Areas 12E (from New Brunswick, PEI and Québec) and 12F (from Nova Scotia and Québec), respectively, in 2011.

The minimum legal carapace width is 95 mm, females are not harvested and soft-shell and white crab is not targeted by the fishery. Baited traps, constructed of wire or tubular steel, are used to catch crab, mainly on mud or sand-mud bottoms at temperatures ranging from -1 to 4.5°C, and depths ranging from 50 to 280m. The fishery takes place from spring to early summer in Areas 12, 12E and 12F and after June 30 in Area 19.

Management of these fisheries is based on quotas and effort controls (number of licenses, trap allocations, trap dimensions, and seasons). There are at-sea soft-shelled and white crab catch monitoring protocols which allow for closure of portions of each fishing area when the proportion of the catch of males exceeds 20%. The protocols are in place to maximize the yield and the reproductive potential of the resource.

Table 1. Number of licenses, vessels, traps, quotas and opening and closing dates in snow crab fishery by management area in the southern Gulf of St. Lawrence in 2011.

	Area				
	12	12E	12F	19	Southern Gulf
Number of licenses	261	8	18	160	447
Number of active vessels	251	4	17	101	373
Total number of traps allowed	30,889	800	1,350	1,699	34,738
Opening date	April 25	April 25	April 19	July 14	
Closing date	July 17	June 06	June 29	August 05	
Quota (t)	8,585	75	314	1,703	10,677
Landings (t)	8,618	76	313	1,701	10,708

The landings from the southern Gulf of St. Lawrence increased from 1969 to the present with three periods of high landings: 1981-1986, 1994-1995, and more recently 2002 to 2009 (Figure 2). The peak landing was reported in 2005 (36,118 t) while the lowest landing was reported in 1975 (4,632 t).

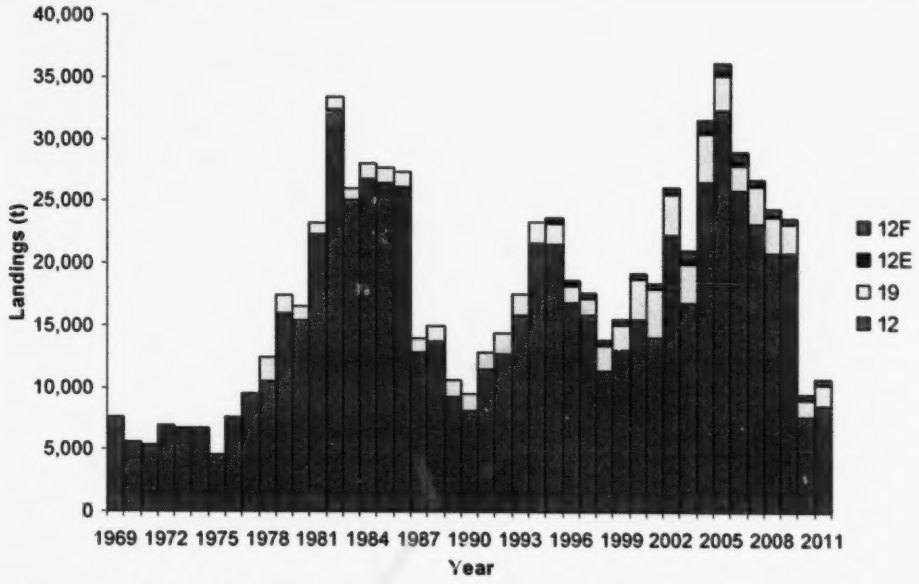


Figure 2: Landings in the southern Gulf of St. Lawrence snow crab fishery.

The 2011 fishing season in Area 12 opened on April 25 and closed on July 17 with reported landings of 8,618 t (quota of 8,585 t) (Tables 1, 2; Figure 2). In accordance with the soft-shelled crab protocol 233 of 323 grids were towards the end of the 2011 fishing season. The fishing effort estimated from logbooks has varied from 243,339 to 544,454 trap hauls between 1987 and 2009, with effort in 2010 and 2011 the lowest of the time series since 1987 (Table 2).

Table 2. Quota, landings, fishing effort and catch performance for the snow crab fishery in Area 12.

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Quota (t)	17,148	26,600	32,336	25,869	23,207	20,900	20,900	7,700	8,585
Landings (t)	16,898	26,626	32,363	25,889	23,243	20,911	20,896	7,719	8,618
CPUE (kg/trap-haul)	50.0	54.9	63.7	64.4	65.7	56.4	48.2	47.9	53.0
Effort (trap hauls)	337,960	484,991	508,053	402,702	353,775	370,762	433,527	161,148	162,604
Soft-shelled crab (%) in catches[1]	3.3	3.0	3.9	3.1	2.0	3.0	5.0	6.5	6.2
Grids closed (total of 323)	0[2]	17	68	11	5	3	78	74	233

[1] Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps

[2] In 2003, the area was divided into four sectors and none of the sectors were closed.

The 2011 fishing season in Area 19 opened on July 14 and ended on August 5 with reported landings of 1,701 t (quota of 1,703 t) (Tables 1, 3; Figure 2). The term white-crab, as used in the summer fishery of Area 19, is defined by shell hardness <72 durometer units. In accordance with the white crab protocol, no sector within Area 19 was closed during the 2011 fishing season. The fishing effort in Area 19 has varied from 16,733 to 55,977 trap hauls between 1987 and 2009 with effort in 2010 and 2011 the lowest of the time series since 1987.

Table 3. Quota, landings, fishing effort and catch performance for the snow crab fishery in Area 19.

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Quota (t)	3,106	5,092	2,878	2,000	3,074	3,002	2,433	1,360	1,703
Landings (t)	3,103	3,894	2,827	1,989	3,034	2,929	2,370	1,360	1,701
CPUE (kg/trap-haul)	103.6	68.9	68.1	84.4	71.3	76.3	71.4	122.1	133.3
Effort (trap hauls)	29,952	56,517	41,512	23,566	42,553	38,388	33,193	11,138	12,761
White crab (%) in catches[1]	3.9	7.9	7.7	6.1	7.4	9.0	11.6	6.4	11.5
Sectors closed[2]	0/4	4/4	0/4	2/4	0/4	4/4	9/9	4/9	0/9

[1] The percentage is based on a durometer reading of 72. Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps

[2] Total numbers of sectors was changed from 4 to 9 sectors in 2009.

The 2011 fishing season in Area 12E began on April 25 and ended June 6 with reported landings of 76 t (quota of 75 t) (Tables 1, 4; Figure 2). The fishing effort in Area 12E increased from 1,825 trap hauls in 2010 to 2,413 trap hauls in 2011. In accordance with the soft-shelled protocol, no grids within Area 12E were closed during the 2011 fishing season.

Table 4. Quota, landings, fishing effort and catch performance for the snow crab fishery in Area 12E.

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Quota (t)	350	350	450	550	221	400	200	67	75
Landings (t)	345	349	449	411	220	187	67	50	76
CPUE (kg/trap-haul)	63.1	55.6	80.6	40.8	37.2	20.3	14.4	27.4	31.5
Effort (trap hauls)	5,471	6,277	5,571	10,074	5,914	9,232	4,653	1,825	2,413
Soft-shelled crab (%) in catches[1]	1.2	1.5	2.9	7.8	1.3	10.1	7.8	14.7	8.4
Grids closed (total of 8)	0	0	0	2	0	0	2	0	0

[1] Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps

In Area 12F, the fishery in 2011 opened on April 19 and closed on June 29 with reported landings of 313 t (quota of 314 t) (Tables 1, 5; Figure 2). The fishing effort decreased from 14,335 trap hauls in 2010 to 9,631 trap hauls in 2011. In accordance with the soft-shelled protocol, no sector within Area 12F was closed during the 2011 fishing season.

Table 5. Quota, landings, fishing effort and catch performance for the snow crab fishery in Area 12F.

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Quota (t)	808	808	480	815	408	585	465	420	314
Landings (t)	817	806	479	787	370	431	309	420	313
CPUE (kg/trap-haul)	78.1	74.8	93.7	55.9	30.2	27.8	22.0	29.3	32.5
Effort (trap hauls)	10,460	10,775	5,112	14,079	12,252	15,504	14,045	14,335	9,631
Soft-shelled crab (%) in catches[1]	0.4	0.6	0.8	3.5	2.4	7.3	11.4	8.6	2.6
Sectors closed (total of 3)	0	0	0	0	1	3	3	2	0

[1] Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps

Catch per unit of effort (CPUE) expressed as kg per trap-haul (kg/th) is calculated from logbook data as the ratio of total landings (kg) to total effort (trap-hauls). In Area 12, the annual unadjusted mean CPUE in 2011 (53.0 kg/th) increased compared to 2010 but remained lower than the peak of 2007 (65.7 kg/th), (Table 2; Figure 3). In Area 19, the CPUE increased in 2011 compared to 2010, and to the highest value since records began in 1987 (Table 3, Figure 3). The CPUE in Areas 12E and 12F increased in 2011 compared to 2010 but remained low compared to historical values (Tables 4, 5; Figure 3).

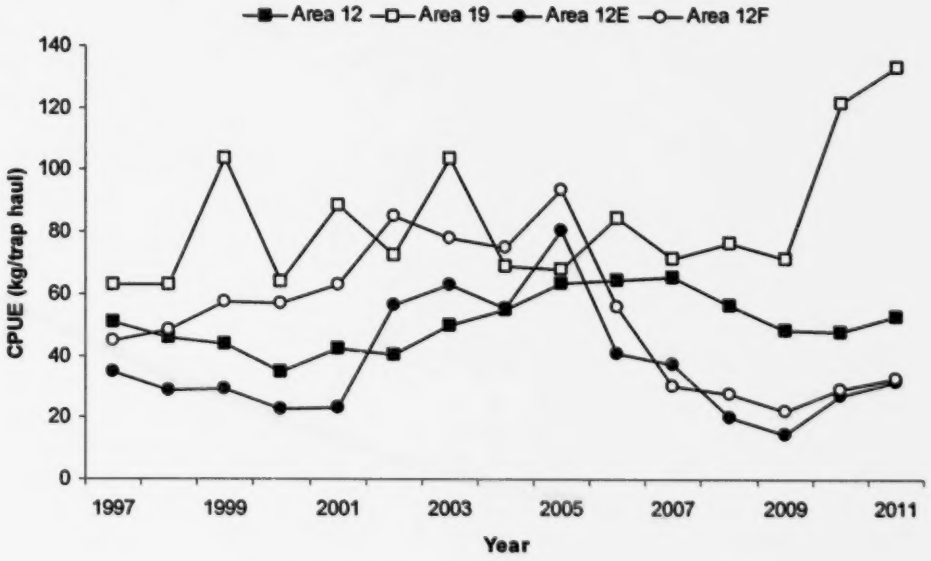


Figure 3: Catch rates in the southern Gulf of St. Lawrence snow crab fishery, Areas 12, 19, 12E and 12F.

The percentage of soft-shelled crab and white crab is calculated using data collected from the at-sea observer program. The incidence of soft-shelled crab and white crab in catches is strongly influenced by the fishing strategy used by harvesters during the season, as well as crab abundance in the area.

The percentage of soft-shelled crab in Area 12 has remained low since 2003 and was at 6.2% in 2011 (Table 2). In Area 19, the percentage of white crab increased from 6.4% in 2010 to 11.5% in 2011 (Table 3). The percentage of soft-shelled crabs in Area 12E decreased from 14.7% in

2010 to 8.4% in 2011 (Table 4). In Area 12F, the percentage of soft-shelled crabs decreased from 8.6% in 2010 to 2.6% in 2011 (Table 5).

As accessory information, the incidence of white crab in landings (i.e. commercial males landed) is also being monitored. The high proportions of white crab in the landings noted in the 2009 and 2010 assessments were examined. The proportions were biased upward due to differences in the categorization of crab carapace conditions by observers from different companies. Additional training provided prior to the 2011 fishery has resolved the discrepancy in observer interpretations and the incidence of white crab is estimated to be a minor component (<2%) of the landings in the southern Gulf snow crab fishery.

ASSESSMENT

The trawl survey was conducted using the procedure defined in the Assessment Framework Workshop of 2005 (DFO 2006), while the survey data was processed according to the recommendations from the Snow Crab Assessment Methods Framework Science Review held during November 21 to 25, 2011, in Moncton, N.B. The major changes recommended by the Snow Crab Assessment Methods Framework Science Review of 2011 were the expansion of the biomass estimation polygon (20 to 200 fathoms corresponding to the areal extent of bottom temperatures < 5 C which are favourable for snow crab) to cover the southern Gulf of St. Lawrence biological unit and the use of kriging with external drift applied to catches in weights (each sampled commercial-sized adult male from a sampling station is converted into weight using the size-weight relationship). The change in methodology required a recalculation of the area estimation polygons (Figure 4; Table 6), the time series of biomass estimates, exploitation rates and the Precautionary Approach reference points.

Snow crab in fishing areas 12, 19, 12E, and 12F comprise a single biological population and the southern Gulf of St. Lawrence stock is considered as one unit for assessment purposes.

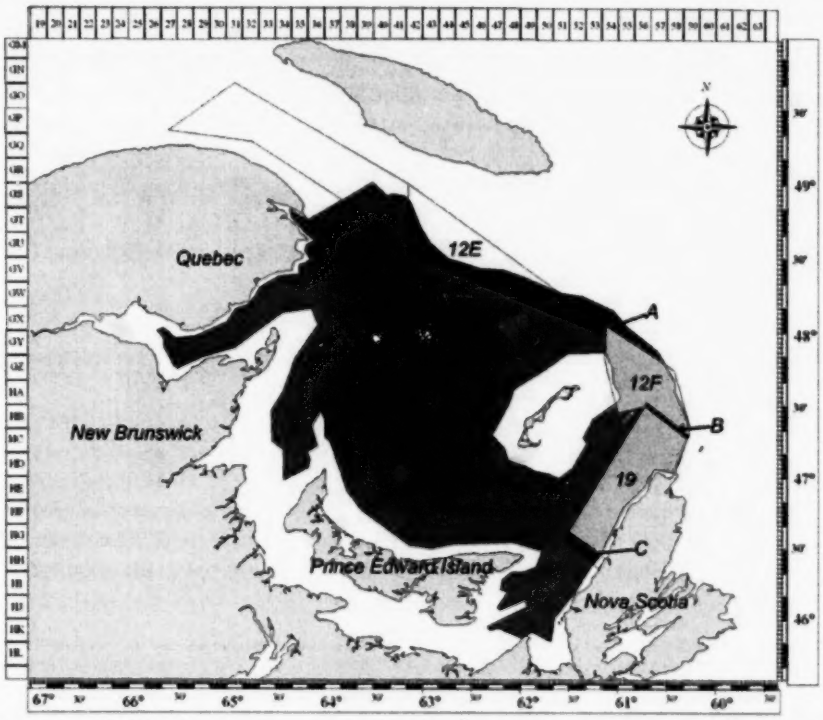


Figure 4. The revised estimation polygon of 57,840 km^2 used for the 2011 snow crab (Chionoecetes opilio) stock assessment in the southern Gulf of St. Lawrence (all of the coloured areas) and corresponding estimation polygons for the four crab fishing areas (12, 12E, 12F, and 19). The unassigned zone north of areas 12E and 12F (label A) and buffer zones (labels B and C) are also shown.

Stock Trends and Current Status in the Southern Gulf

Statements of stock status are based on inferences from abundance data from annual trawl surveys conducted during July to October, over the entire area of snow crab distribution in the southern Gulf. This provides estimates of commercial biomass which are comprised of residual biomass (hard-shelled adult males of legal size remaining after the fishery) and recruitment biomass (soft-shelled adult males >= 95 mm CW (R-1) that will be available to the fishery the following fishing season). It also provides estimates of future male recruitment to the fishery (prerecruits defined as R-4, R-3 and R-2). The prerecruits R-4, R-3 and R-2 represent adolescent male crabs with a carapace width range of 56-68, 69-83, and larger than 83 mm, respectively. A portion of these crabs could be available to the fishery in 4, 3 and 2 years, respectively. The abundances of small adolescent male instar VIII (34-44 mm CW) were also estimated as an indicator of long-term recruitment. It takes at least six years for an adolescent male of instar VIII to reach the commercial size of 95 mm CW.

A second fishery independent survey of the southern Gulf is used to provide an index of abundance of commercial-sized male crab. The multi-species research vessel bottom trawl survey, a stratified random design, has been conducted annually in September since the early 1970's although the index of commercial male crab (>= 95 mm) abundance begins in 2001.

Spawning stock abundance consists of females (pubescent and mature). The term pubescent refers to females that will molt to maturity and mate the following year and become primiparous

females (first brood). The term 'multiparous' refers to females which are carrying a brood for the second time or more. The term 'mature females', includes primiparous and multiparous females.

The biomass of commercial-sized adult males in the southern Gulf of St. Lawrence from the 2011 trawl survey was estimated at 63,162 t with 95% confidence limits of 55,965 t to 71,022 t (Table 6; Figure 5). The estimated commercial biomass in the southern Gulf increased by 76% relative to 2010 (35,795 t; 95% C.I. 31,681 t - 40,291 t).

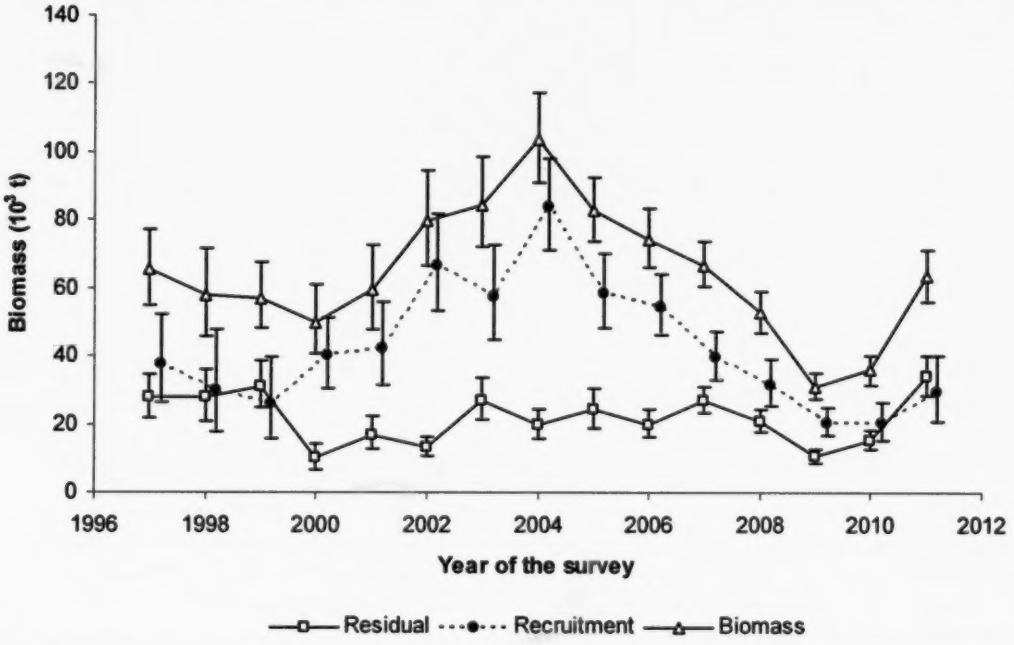


Figure 5: Total commercial biomass, recruitment commercial biomass, and residual commercial biomass (with 95% confidence intervals) in the southern Gulf of St. Lawrence, 1997 to 2011.

The September multi-species bottom trawl survey index shows similar trends in commercial male snow crab abundance between 2001 and 2011 as the biomass estimates from the dedicated snow crab survey (Figure 6). The index of abundance declined from 2008 to 2009, remained low in 2010 and increased in 2011.

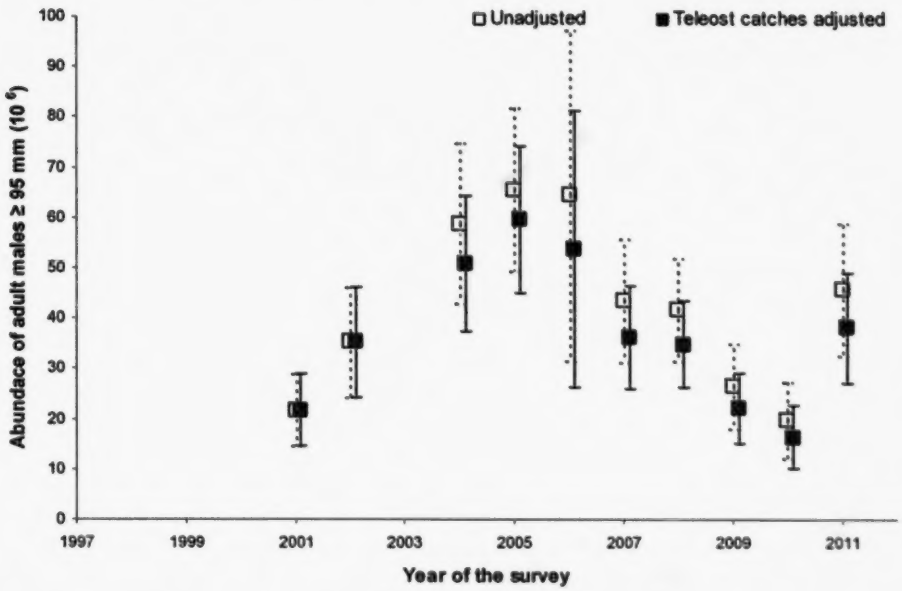


Figure 6. Trawlable abundance (± 95% confidence interval) of mature male snow crab ≥95 mm in the September RV survey 2001-2011. Series are presented for CCGS Teleost vessel catches that are (closed symbols) or not (open symbols) adjusted for a possible difference in fishing efficiency with the CCGS Alfred Needler, the vessel used in the survey until 2005.

As requested by DFO Fisheries and Aquaculture Management, the 2011 commercial biomass estimates in snow crab fishing areas (12, 19, 12E and 12F), two buffer zones (northern buffer zone between areas 12F and 19, and southwest buffer zone between areas 12 and 19) and the unassigned zone (north of areas 12E and F), as shown in Figure 4, are summarized in Table 6. The majority of biomass was found in Area 12, followed by Area 19, 12F, 12E, southern buffer zone, northern buffer zone and the unassigned zone.

The residual biomass (carapace conditions 3 to 5) of commercial sized male crab after the 2011 fishery was estimated at 33,768 t (95% C.I. 28,297 t to 39,985 t), an increase of 119% relative to 2010 (Table 7; Figure 5). The recruitment to the fishery at the time of the survey was 29,394 t (95% C.I. 20,909 t to 40,190 t), comprising 47% of the commercial biomass (Table 7; Figure 5). The recruitment to the fishery in 2011 increased by 44% compared to the 2010 estimate. The estimate of residual biomass in 2011 is abnormally high relative to the expected value from the 2010 survey and the fishery in 2011. This discrepancy may be due to a number of factors including misattribution of recruitment (carapace conditions 1 and 2) in 2011 to residual biomass (especially carapace condition 3) due to variations in molting period and carapace hardening during 2010 and 2011, possible underestimates of biomass in 2009 and 2010 and / or overestimates of biomass in 2011 (including variations in survey catchability), and immigration of crab from outside the southern Gulf biological unit.

Table 6. Estimates of commercial biomass (t, mean and 95% confidence interval range) in 2011 for the southern Gulf and by snow crab fishing areas 12, 19, 12E and 12F, in buffer zones and the unassigned zone for the revised estimation polygon of 57,840 km^2. Labels refer to those in Figure 4.

Areas	Surface area (km^2)	Commercial biomass (t)	
		Mean	95% confidence intervals
Southern Gulf	57,840	63,162	(55,965-71,022)
Area 12	48,028	51,381	(45,110-58,274)
Area 19	3,833	8,346	(7,245-9,565)
Area 12E	2,443	705	(162-2,023)
Area 12F	2,438	1,900	(1,135-2,993)
Sum of crab fishing areas	56,742	62,332	
Buffer zone 19 /12F (label B)	112	112	(44 – 239)
Buffer zone 12/ 19 (label C)	310	684	(424-952)
Unassigned zone above 12E and 12F (label A)	674	32	(0-235)
Total	57,838	63,160	

In the 2011 trawl survey, geographic concentrations of commercial-sized adult males were located in Chaleur Bay, American Bank, Bradelle Bank, Shediac Valley, southern part of the Magdalen Channel and notably in the west of Cape Breton Island (Figure 7). The spatial distributions of commercial-sized adult males have varied annually during increasing and decreasing phases of the commercial biomass (Figure 8).

Table 7. Total commercial, recruitment, and residual biomass (t; mean with 95 % confidence intervals) of commercial-sized adult males >= 95 mm in the southern Gulf of St. Lawrence.

Year of the survey	Commercial Biomass (t)	Recruitment Biomass (t)	Residual Biomass (t)
1997	**65,310** 54,801-77,239	**37,619** 26,376-52,064	**27,690** 21,995-34,407
1998	**57,595** 45,630-71,735	**29,818** 17,580-47,435	**27,775** 21,022-36,013
1999	**57,051** 47,946-67,376	**25,874** 15,918-39,818	**31,177** 25,051-38,346
2000	**49,823** 40,473-60,682	**39,845** 30,543-51,093	**9,977** 6,649-14,401
2001	**59,150** 47,740-72,460	**42,243** 31,198-55,942	**16,905** 12,657-22,125
2002	**79,559** 66,688-94,181	**66,481** 53,434-81,746	**13,075** 10,451-16,157
2003	**84,423** 71,964-98,410	**57,503** 44,809-72,679	**26,919** 21,223-33,674
2004	**103,429** 91,029-117,036	**83,702** 70,955-98,069	**19,726** 15,836-24,280
2005	**82,537** 73,487-92,387	**58,398** 48,417-69,824	**24,140** 18,726-30,632
2006	**74,285** 66,192-83,087	**54,371** 46,124-63,660	**19,914** 16,161-24,275
2007	**66,660** 60,183-73,638	**39,635** 33,089-47,092	**27,025** 23,354-31,106
2008	**52,564** 46,658-59,006	**31,555** 25,181-39,048	**21,010** 17,960-24,426
2009	**30,920** 27,237-34,959	**20,520** 16,848-24,754	**10,399** 8,560-12,516
2010	**35,795** 31,681-40,291	**20,351** 15,360-26,450	**15,444** 12,859- 18,394
2011	**63,162** 55,965-71,022	**29,394** 20,909-40,190	**33,768** 28,297- 39,985

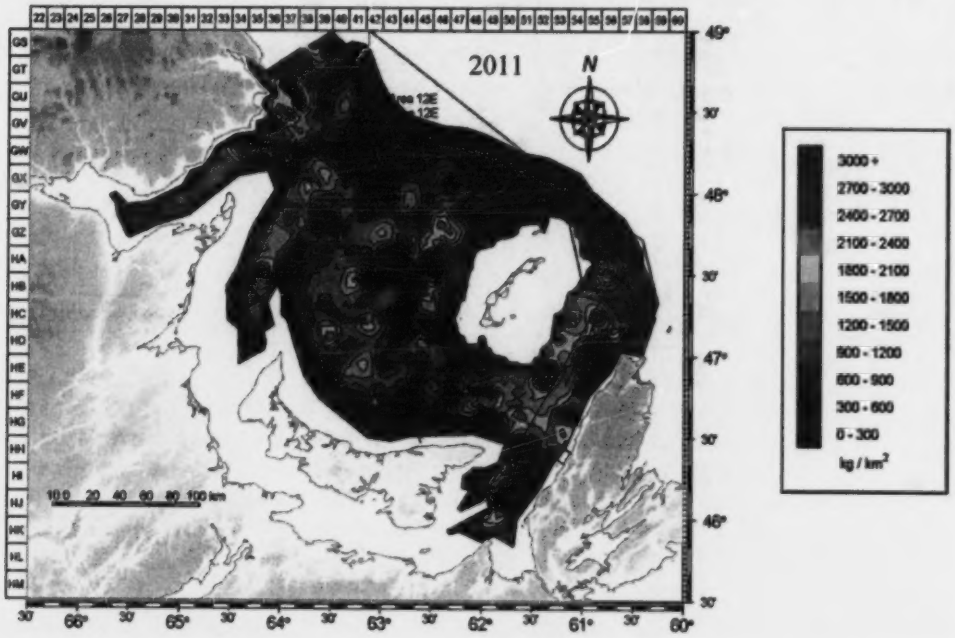


Figure 7: Density (kg per km²) contours of commercial sized adult male crab (≥95 mm CW) in the southern Gulf of St. Lawrence in 2011.

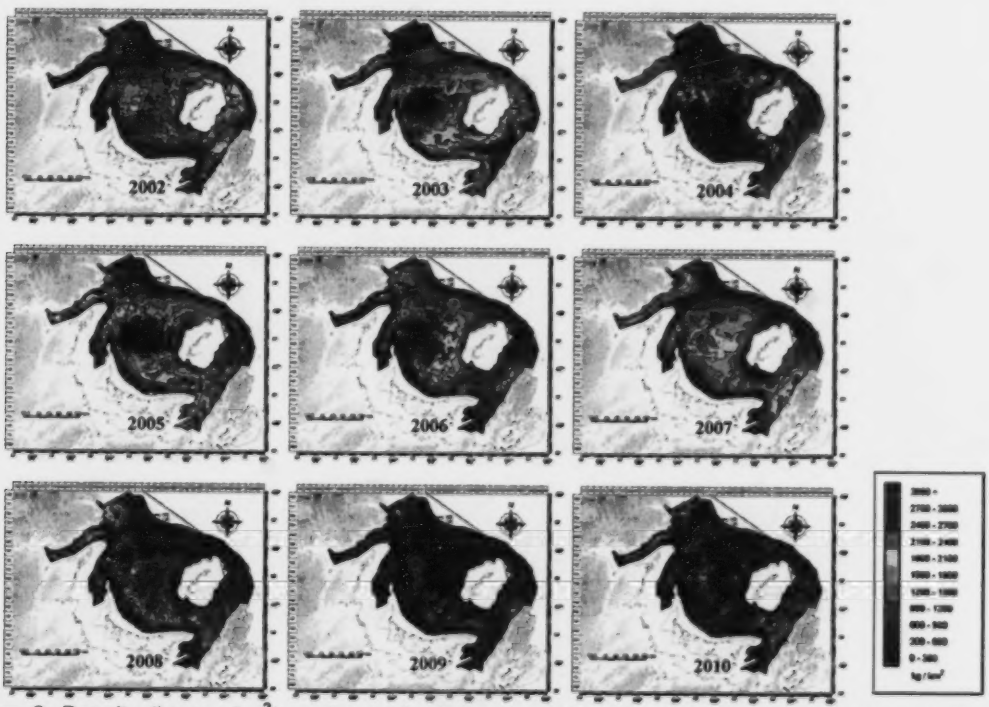


Figure 8: Density (kg per km²) contours of adult male crab (≥95 mm CW) in the southern Gulf of St. Lawrence, 2002 to 2010.

The exploitation rate in the southern Gulf of St. Lawrence in 2011, which is the ratio between the catch of the 2011 fishery and the commercial biomass estimated from the 2010 trawl survey, was 29.9%. The exploitation rates varied between 21% and 45% from 1998 to 2011 (Figure 9).

In 2011, the total mortality, expressed as a proportion of residual biomass from the survey in 2011 to estimated biomass available to the fishery from the 2010 survey, was estimated at 5.6% (Figure 9). This value is not comparable to other years as the fishery exploitation rate based on the 2010 biomass estimate (29.9%) is higher than the calculated total loss (5.6%) based on residual biomass in 2011 and commercial biomass in 2010 (Figure 9).

The commercial biomass estimate from the trawl survey of 2010 was 24% lower than the sum of the residual biomass from the trawl survey in 2011 plus the landings in 2011. This discrepancy may be due to a number of factors including misattribution of recruitment (carapace conditions 1 and 2) in 2011 to residual biomass (especially carapace condition 3) due to variations in molting period and carapace hardening during 2010 and 2011, possible underestimates of biomass in 2009 and 2010 and / or overestimates of biomass in 2011 (including variations in survey catchability), and immigration of crab from outside the southern Gulf biological unit. In 2010, the difference was 19% higher and the average difference over the time series has been 34% higher. This difference (termed non-fishing directed mortality) was attributed to a number of factors including variability in survey estimates, natural mortality, fishery induced mortalities, as well as emigration out of the sampled area.

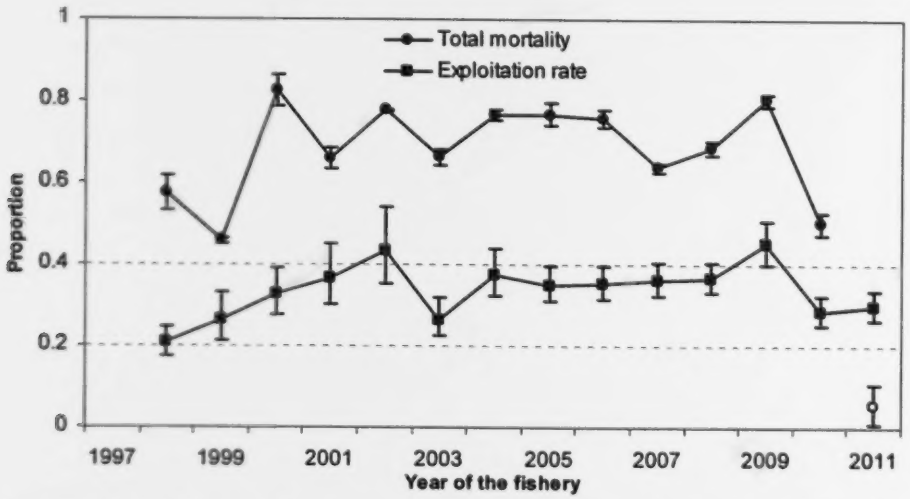


Figure 9: Exploitation rates by the fishery and total mortality of commercial-sized adult male snow crab in the southern Gulf of St. Lawrence, 1997 to 2011. The 2011 total mortality point is isolated from the series due to uncertainties in the components of the 2011 survey biomass as indicated in text.

An increasing trend in recruitment of commercial-sized adult male crab to the fishery is anticipated until the 2014 fishery based on abundances of adolescent males of R-2, R-3 and R-4 from recent surveys (Figures 10 and 11). The abundances of male Instar VIII (34-44 mm CW) observed in the trawl surveys in 2011 are comparable to the peak observed in 2007 (Figure 12).

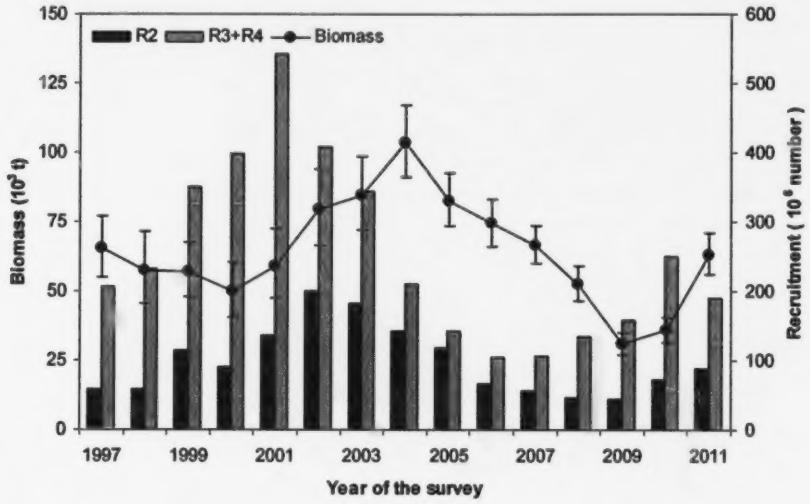


Figure 10: Survey biomass (commercial-sized adult males; mean with 95% confidence intervals) and abundance of future recruitment (R2, R3 and R4) in the southern Gulf of St. Lawrence.

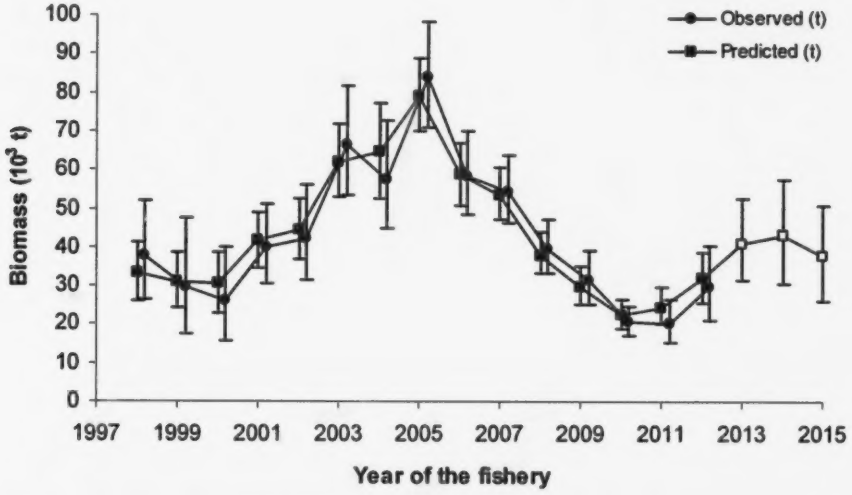


Figure 11: Observed versus predicted recruitment of R-1 (adult male >= 95 mm CW) snow crab in the year of the fishery based on the abundances of R-2 (adolescent male crab larger than 83 mm CW) the previous year.

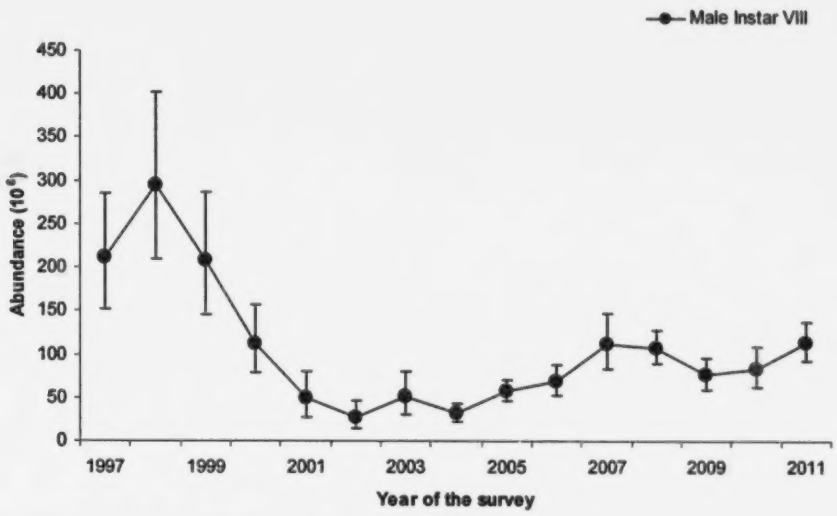


Figure 12: Abundance estimates (number of individuals, mean with 95% confidence intervals) of juvenile male crab at Instar VIII (34 to 44 mm CW), based on the trawl surveys conducted in the southern Gulf of St. Lawrence, 1997 to 2011.

Reproduction

The abundance of mature females remained high in 2011 relative to the low values observed during 2005 to 2009 (Figure 13). However, the continued low abundance of pubescent females in the population in recent years suggests that the abundance of mature females will remain low in the coming years compared to the peak observed in 1999 (Figure 13).

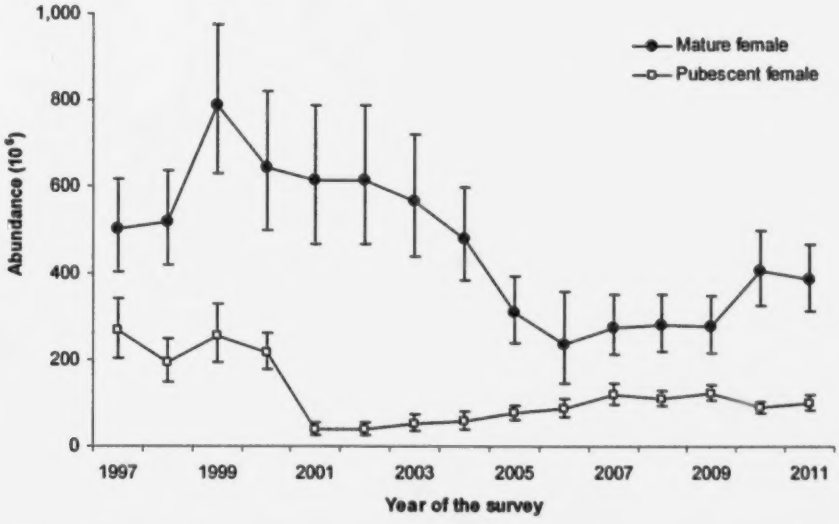


Figure 13: Annual female abundance estimates (number, mean with 95% confidence intervals) in the southern Gulf of St. Lawrence based on the trawl surveys.

Sources of Uncertainty

A Snow Crab Assessment Methods Framework Science Review was conducted in November 2011 to address concerns about the variations in survey design and sample coverage, the standardization of area swept, and the area of the estimation polygon to be used. Following the review, it was agreed that the biomass time series from 1997 to the present was a coherent time series to be used in assessing stock status and providing catch advice. Further work was required to determine if the earlier part of the time series between 1989 and 1996 for which survey coverage for the southern gulf was much less than the coverage from 1997 to the present, could also be used to assess snow crab abundance in the southern Gulf.

The estimate of residual biomass in 2011 is abnormally high relative to the expected value from the 2010 survey and the fishery in 2011. This discrepancy may be due to a number of factors including misattribution of recruitment (carapace conditions 1 and 2) in 2011 to residual biomass (especially carapace condition 3) due to variations in molting period and carapace hardening during 2010 and 2011, to underestimates of commercial biomass in 2009 and 2010 and / or overestimates of biomass in 2011 (including variations in survey catchability), and immigration of crab from outside the southern Gulf biological unit. The possible accelerated hardening of newly molted crab becomes an issue the later the survey timing which may support the possibility of misattribution of recruitment to residual biomass in 2011. Year effects in survey biomass estimates (due to variations in survey catchability) can be verified using a secondary fishery independent survey such as the September multi-species survey.

Temperature in the southern Gulf varies annually. In recent years, the temperatures have been above normal and the index of suitable habitat for crab has declined. These changes in temperature can affect a number of life history processes including molting and growth, reproduction, larval development and the impacts of warming conditions on the snow crab life history are not well understood.

CONCLUSIONS AND ADVICE

Within the Precautionary Approach (PA) framework (DFO 2009), the Limit Reference Point for biomass (B_{lim}) defines the critical / cautious zones and an upper stock reference (B_{USR}) delimits the cautious / healthy zones on the stock status axis. A removal rate limit reference point (F_{lim}) defines the maximum removal rate in the healthy zone. The change in methodology derived from the Snow Crab Assessment Methods Framework Science Review held during November 21 to 25, 2011, in Moncton, N.B. required the recalculation of the time series of biomass estimates and the Precautionary Approach reference points. The rescaled upper stock reference point (B_{USR}) is 41,400 t of commercial-sized adult males of all carapace conditions as estimated from the trawl survey (DFO 2012). These crabs become hard shelled commercial-sized adult males by January of the year following the trawl survey. The rescaled biomass limit reference point (B_{lim}) value is 10,000 t (DFO 2012). The biomass limit reference point was chosen as the lowest biomass of hard shelled commercial-sized adult males which produced good recruitment rates of Instar VIII (DFO 2010). The rescaled removal reference point (F_{lim}) has been set at 34.6%, which is the average of the exploitation rates calculated as catch (weight) in year t+1 divided by the estimated biomass of commercial-sized adult male crab from the post-fishery trawl survey in year t for the 1998 to 2009 fishery years (DFO 2012). The southern Gulf of St Lawrence commercial biomass estimate should be used for evaluating catch options relative to the defined reference points.

The trajectory of stock abundance (biomass of commercial-sized adult male crab from the fall

trawl survey in year t - 1) versus exploitation rate on this biomass in the fishery of year t is shown in Figure 14. The commercial biomass has varied between 30,920 t and 103,429 t during 1998 to 2011. Over this same period, exploitation rates have varied between 20.8% and 45.0%. The estimated biomass from the 2011 fall survey, which would be available to the fishery in 2012, was 63,162 t (95% CI 55,965 - 71,022 t). The 2011 survey biomass estimate is in the healthy zone of the PA framework. When the stock is in the healthy zone, the exploitation regime should not exceed F_{lim} (34.6%).

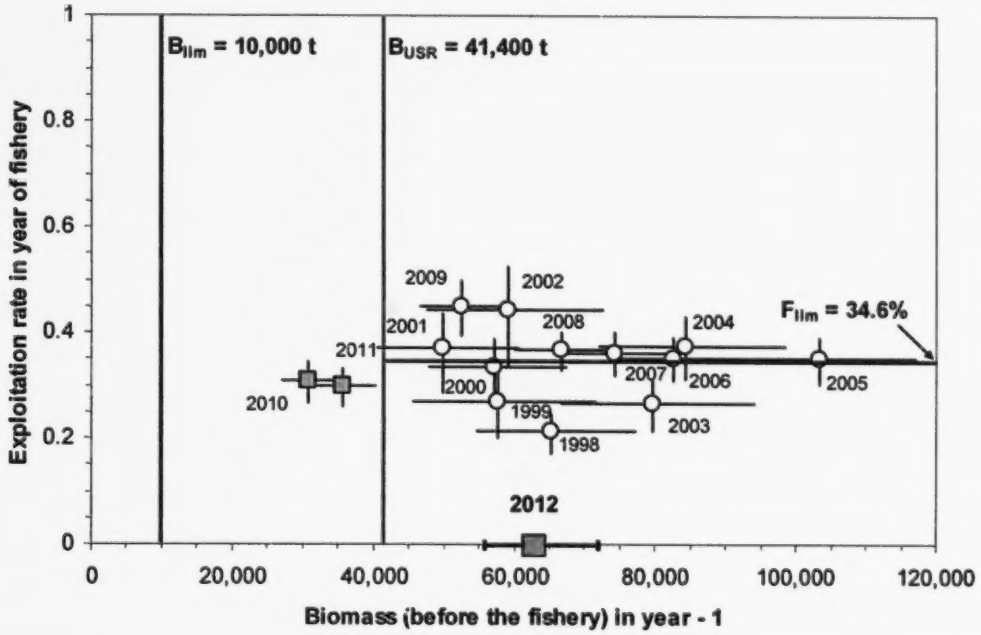


Figure 14: Trajectory of stock abundance (biomass of commercial-sized male crab as estimated from the trawl survey in year – 1) versus exploitation rate of this biomass in the fishery of year t. Year of the fishery is labeled on the figure. Error bars are 95% confidence interval ranges. White symbols are biomass and exploitation rate levels used to define the reference points. The grey squares are the years when the reference points were used within the PA to decide on the fishery quota. The biomass estimate available for the 2012 fishery (with 95% confidence interval range) is also shown.

A risk analysis was developed relative to various catch options in 2012 (Table 8; Figures 15 and 16). The decision rules to put in practice the PA remain to be defined.

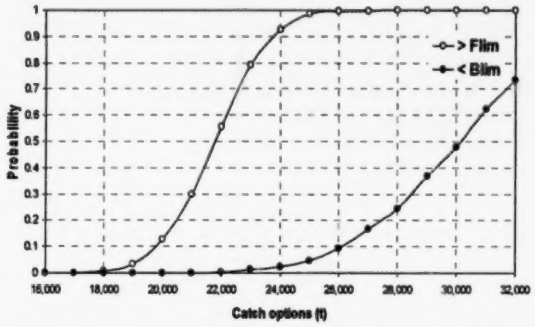


Figure 15: Risk analysis for the southern Gulf of St. Lawrence snow crab fishery showing probabilities of exceeding F_{lim} and of the hard-shell commercial-sized adult male biomass in 2012 falling below B_{lim} for different catch options in 2012.

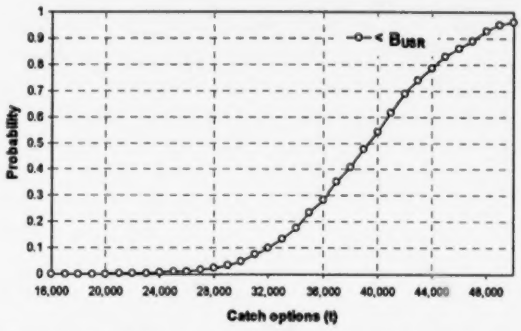


Figure 16: Risk analysis for the southern Gulf of St. Lawrence snow crab fishery showing probabilities that the commercial-sized adult male biomass in 2012 will be below B_{USR} after the 2012 fishing season for different catch options in 2012.

Table 8. Risk analysis for different catch options in 2012 for the southern Gulf of St. Lawrence snow crab fishery showing probabilities of exceeding F_{lim}, of the hard-shell commercial-sized adult male remaining biomass falling below B_{lim}, and of the total commercial-sized adult male biomass being below B_{USR} post-fishery in 2012.

	Probability		
Catch Options (t)	**> F_{lim} = 34.6%**	**< B_{lim} = 10,000 t**	**< B_{USR} = 41,400 t**
16,000	0	0	0
17,000	0.001	0	0
18,000	0.006	0	0
19,000	0.035	0	0
20,000	0.126	0	0.001
21,000	0.297	0.001	0.002
21,854	0.5	0.002	0.002
22,000	0.556	0.003	0.004
23,000	0.792	0.013	0.004
24,000	0.926	0.023	0.006
25,000	0.988	0.048	0.01
26,000	0.996	0.093	0.012
27,000	0.998	0.169	0.019
28,000	0.999	0.246	0.025
29,000	1	0.369	0.033
30,000	1	0.48	0.05
31,000	1	0.624	0.076
32,000	1	0.735	0.101

OTHER CONSIDERATIONS

Ecosystem Considerations

Snow crab is a stenothermic species with a preference for colder water temperatures. A temperature regime shift from cold to warm may have impacts on population dynamics of snow

crab such as shortened reproductive cycles, increased per capita fecundity, increased size at maturity, greater natural mortality, spatial contraction of habitat, and skewed sex ratio for reproduction. The climate-driven change in is more vulnerable to commercial fishing pressure especially in an increasing temperature condition. Furthermore, the direction and outcome of climate change on snow crab population dynamics can be relatively abrupt and even detrimental to abundance (Sainte-Marie et al. 2008).

The crabs caught during the annual snow crab surveys were found in slightly warmer waters in 2011 than in 2010, a situation that is amplified by the lack of sub-zero temperatures over the Southern Gulf.

Near-bottom temperatures in the southern Gulf of St. Lawrence (Magdalen Shallows) and in the northeastern Scotian Shelf during 2011 were examined primarily from data collected during the snow crab and multi-species surveys. The snow crab survey was conducted in July-October, while the multi-species survey was in September only. Data from the multi-species surveys, which are available for a much longer period than those from the snow crab survey, were compared to their normal conditions (1981-2010). Additional temperature data from other fisheries surveys and oceanographic studies in these same areas were also examined. In the southern Gulf of St. Lawrence during 2011, conditions were variable, but similar to the previous year (2010) except for Chaleur Bay, Shediac Valley and the area northeast of Magdalen Islands where conditions warmed up compared to 2010. The area between PEI and Magdalen Islands cooled down during the year. Near bottom temperatures over a large portion of the Southern Gulf were markedly above the long-term average.

The warmer bottom water is somewhat consistent with a decrease in the Gulf wide snow crab thermal habitat index (area of the bottom covered by water temperatures between –1 and 3 °C) relative to 2010 and the thermal habitat index is the lowest of the time series since 1981 (Figure 17). The mean temperature within the habitat area in 2011 is similar to 2010 but increased significantly compared to 2009 (Figure 17). The 2010 and 2011 values are much higher than the long-term mean and represent the highest points since 1982 when the maximum of the time series was reached. The 2011 core temperature is the third highest value of the time series.

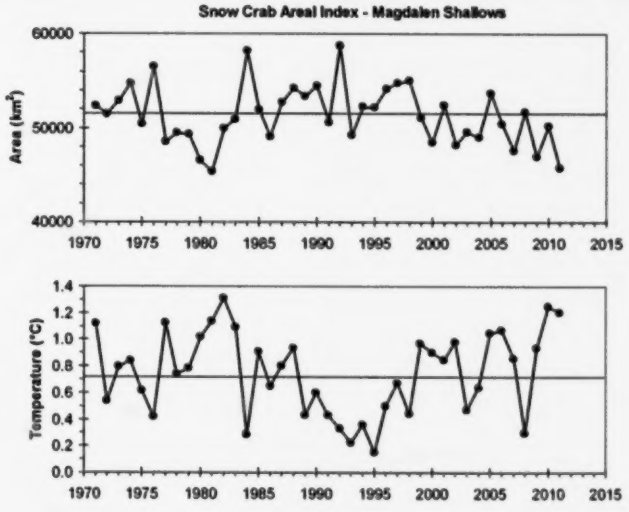


Figure 17: Snow crab temperature habitat area index and mean temperature within the temperature area index in the southern Gulf of St. Lawrence.

SOURCES OF INFORMATION

This Science Advisory Report is from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, regional advisory meeting of February 7-8, 2012 on the assessment of the status of the southern Gulf of St. Lawrence snow crab stock. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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FOR MORE INFORMATION

Contact: Mikio Moriyasu
Science Branch
Fisheries and Oceans Canada
Gulf Region
P.O. Box 5030
Moncton, N.B. E1C 9B6

Tel: (506) 851-6135
Fax: (506) 851-3062
E-Mail: Mikio.moriyasu@dfo-mpo.gc.ca

This report is available from the:

Centre for Science Advice (CSA)
Gulf Region
Fisheries and Oceans Canada
P.O. Box 5030
Moncton, NB
E1C 9B6

Telephone: 506 851 6253
Fax: 506 851 2620
E-Mail: csas-sccs@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

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